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246860-7-0

Shipboard IRST Support

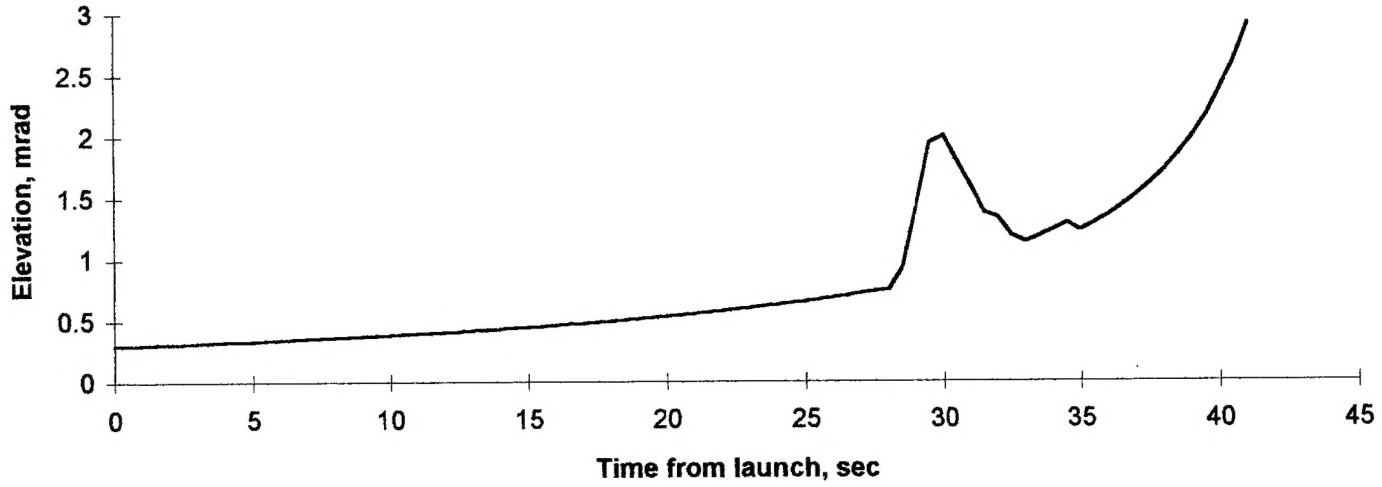
Final Briefing to
Office of Naval Research
October 1994

Environmental Research Institute of Michigan

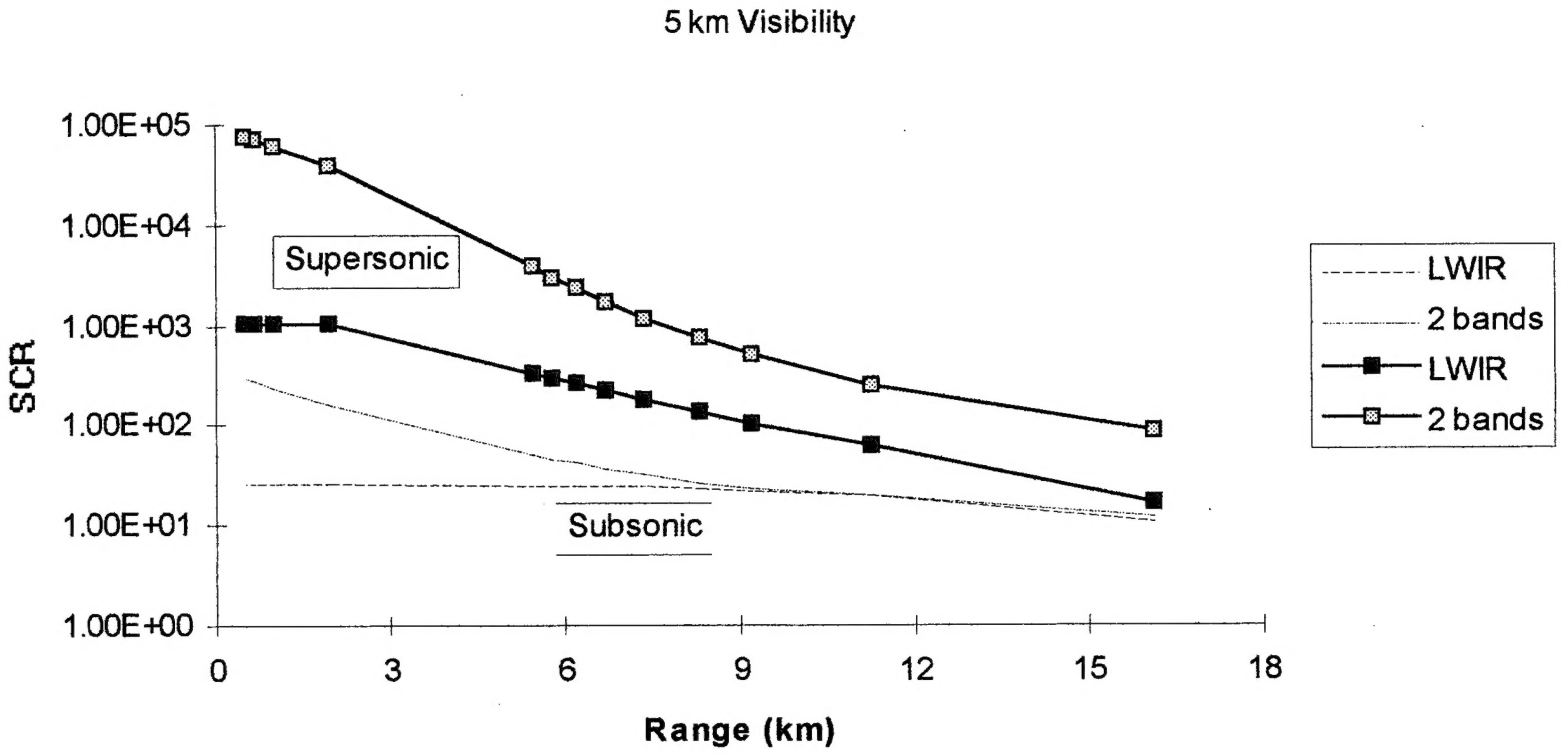
Project Tasks

- Target vehicle signature
  - dynamic variation due to maneuvers (including effects of guidance and control)
  - vehicle reflectance properties
- Environmental effects
  - atmospheric refraction (including turbulent effects)
  - emission and reflection from opaque backgrounds
- Sensor Trade Studies
- Advanced Discriminants
  - selection of spectral band or bands
  - spectral diversity.

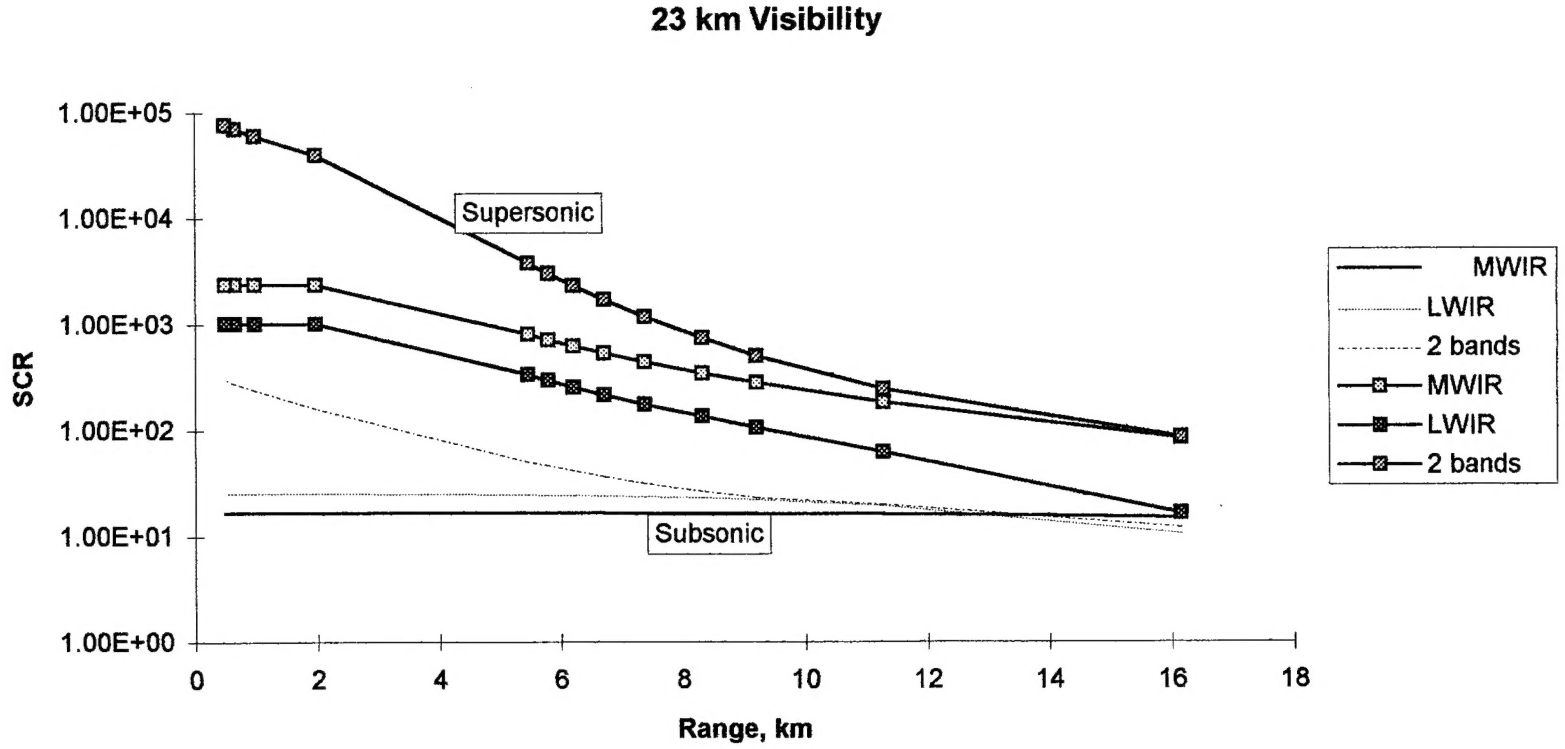
Elevation Variation during CM Approach



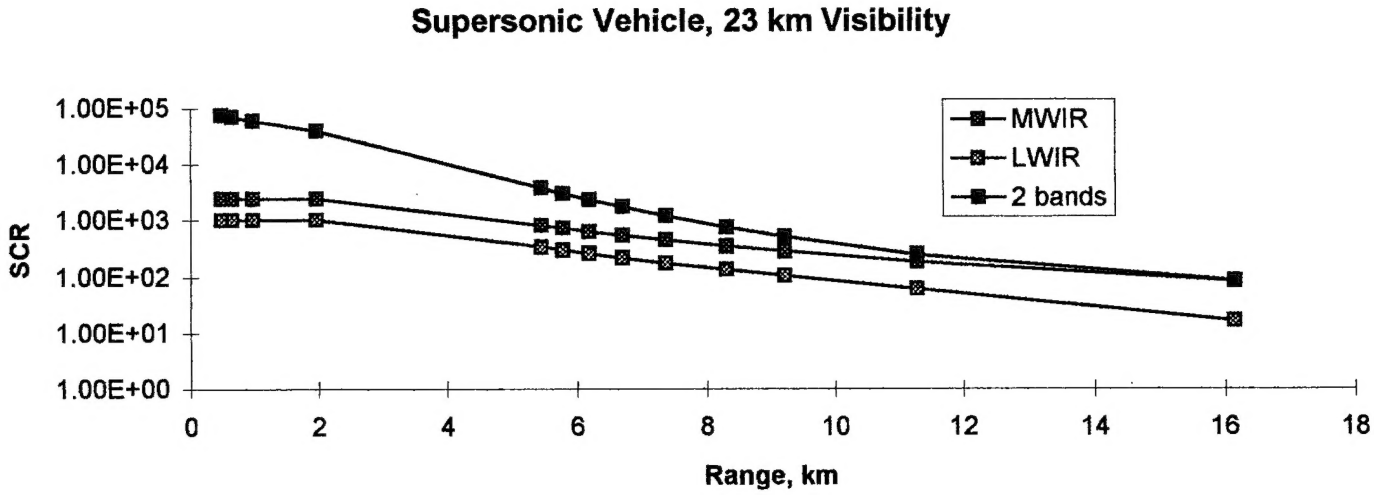
Multispectral Gain for Two Target Classes



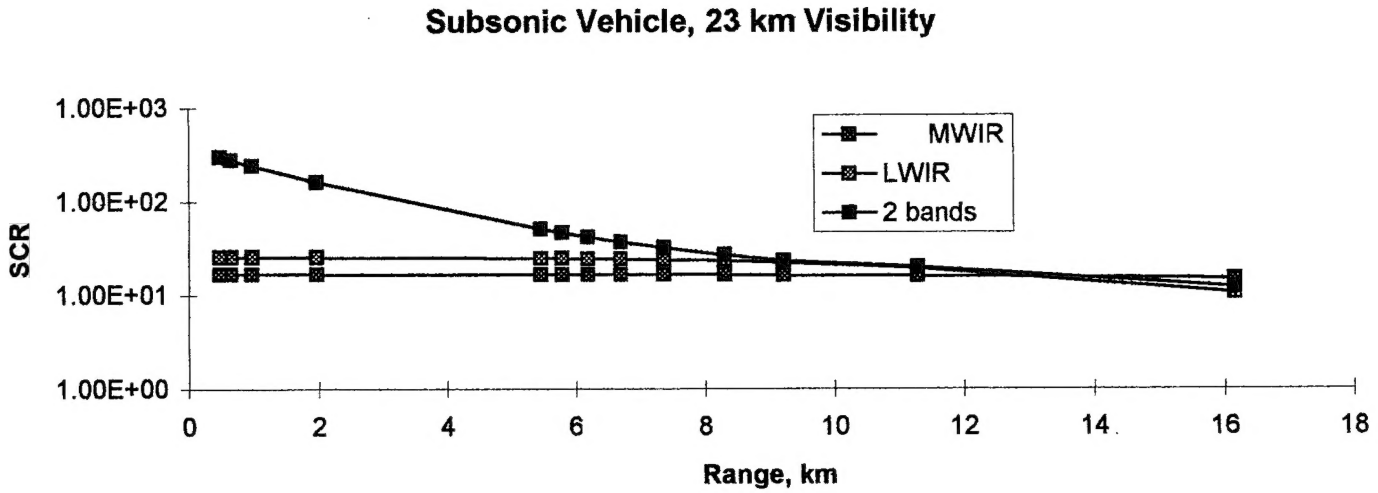
Multispectral Gain, Good Visibility



Multispectral Gain, Good Visibility



Multispectral Gain, Good Visibility (Cool Vehicle)



Coating Effects on Target Signature

- Detection ranges are sensor noise limited not clutter limited
- BRDF of various aircraft coatings are not all diffuse
- Specularity decreases target contrast and therefore SCR since target signal is primarily reflected background and not thermal emission from the target itself

Glossy Coating

- The reduction in SCR is apparent
- Multispectral processing does have some small benefit when the target has a glossy coating

Target Insertion in Backgrounds

- Target-environment interaction
  - reflectance of the environment from target surfaces
  - heat transfer from the environment
  - occultation of the background by the target
- Point targets
  - will appear as an Airy spot filling more than one detector
  - technique for efficiently inserting point targets
    - » **compute the FFT of a single pixel**
    - » **phase shift the transform to give it the correct sub-pixel shift**
    - » **multiply by the MTF of the IRST optics and detector**
    - » **inverse transform and add the radiance to the image**

Extended Target Insertion

- Edges must be blended properly with the background
- Compute target signature for chips which include a portion of clutter surrounding the target
- Spatial sample interval should be no more than half of that of the final image

Transmission and Path Radiance

- Transmittance can be as small as 6-10% even with high visibilities.
- For long ranges, SCR dominated by the sensor noise.
- Short range SCR is dominated by background clutter.
- Path radiance adds a bias to the signals detected by an IRST.
  - At long ranges it can fill a significant portion of the detector dynamic range
  - Random photon arrival times of this energy can increase the level of noise added to the signal by the sensor

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Turbulence and Scintillation

- Turbulence will also cause the scintillation of extended sources, such as the background clutter.
- Variance will be less than that of a point source due to spatial averaging over the extended background.
- Refractive index structure parameter is a weak function of wavelength.

Vertical Refractive Index Gradients

- Temperature increases with altitude
  - Air density decreases with height
  - Light rays are bent toward the Earth
  - This can cause the image of an object to appear:
    - » **above its true position (looming)**
    - » **to have an angular size larger (towering)**
    - » **smaller (stooping) than the true angular extent**
- Temperature decreases with altitude
  - Air density increases with height and light rays are bent away from the earth.
    - » **Causes the image to appear below its true location (sinking).**
    - » **Unstable atmosphere causes turbulence that produces fluctuations in image location as well as scintillation**

ONR Sensor at Diamond Shoals

- Shows a distinct horizon with an elevation that changes by as much as three pixels
  - Could be attributed to "giant waves" [Takken, et al., 1993]
  - Similar to undulations seen in the visible images taken from a video tape
- Features were observed to propagate with the wind at speeds that are improbably high for low frequency "giant" waves
- Possible that these features are due to an air mass having azimuthal changes in the temperature profile propagated across the field of view by winds

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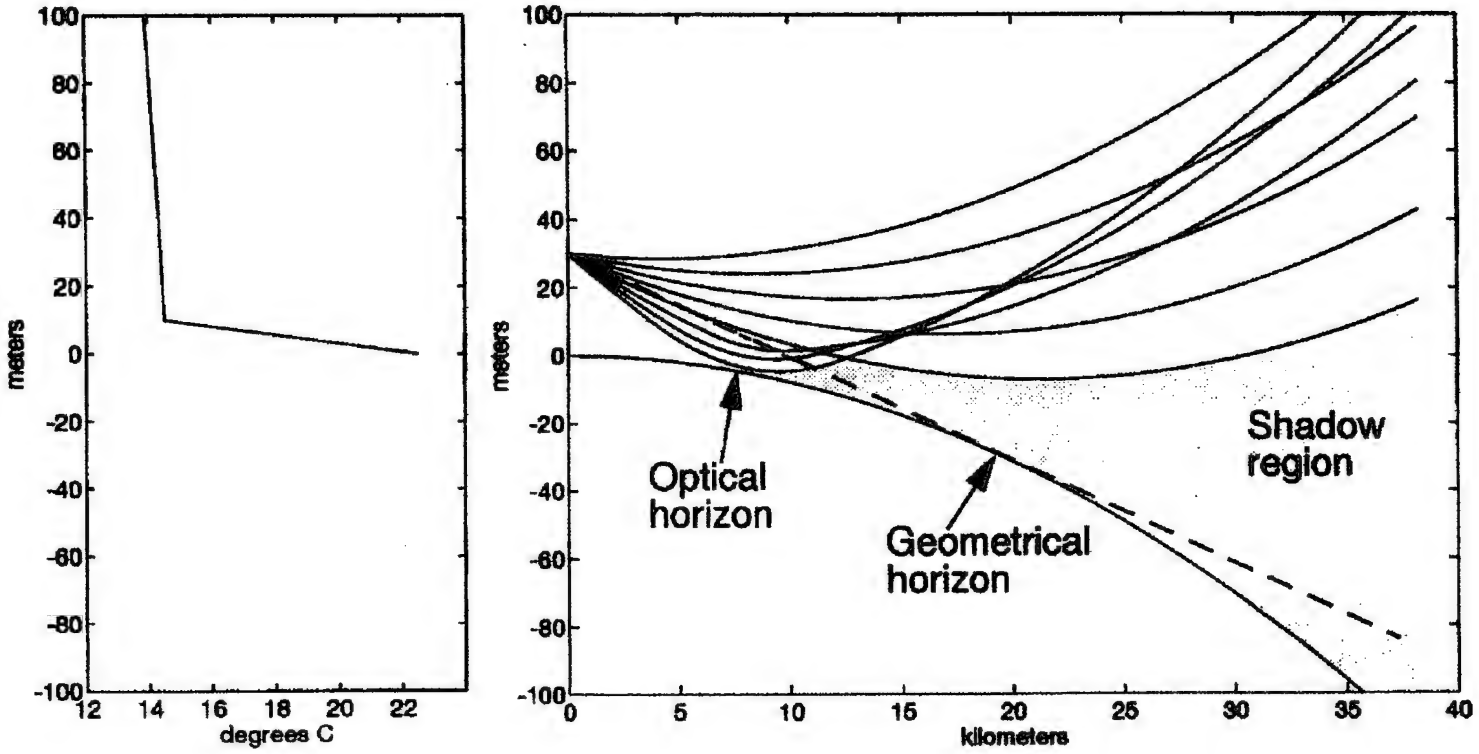
Shadow Zones

- The optical horizon occurs where the rays are tangent and intersect the Earth's surface.
- Horizon is closer under these conditions
- There is a region below the optical horizon yet above the geometrical horizon in which targets cannot be seen.
- Analogous to shadow regions in sonar

Shadow Zone


meters
degrees C
Optical horizon
Geometrical horizon
Shadow region
kilometers

Temperature Data Availability

- Standard meteorological practice is to measure air temperature at least two meters above the surface to avoid surface effects.
- Temperature measurements are usually made at a single height
- Profiles of the fifty meters closest to the ground are not generally available
- Majority of temperature data collected world wide is of little use in determining what profiles should be used in any particular situation or location

Sensor Trade Studies

- Multispectral and temporal processing of imagery from the AADEOS sensor
- AADEOS sensor is capable of preserving at least two nines (0.99) of correlation in the data collected.

Statistical Characterization

- Estimate of clutter and correlation levels from four locations in images
- Fifty contiguous sky pixels used to characterize sensor noise levels
- Estimates made of correlation lengths of four types of backgrounds after removing linear trend

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Conclusions

- Some targets exhibit anomalous relative motion
  - effect pronounced during turns
  - non-linear motion may impact target detection performance
- Multispectral processing results in modest gain for standard targets in an open ocean scenario.
  - More gain is realized against targets with advanced (reflective) coatings.
  - Greater payoff for multispectral is expected for an cruise missile viewed against a land background.
  - The use of multispectral processing for combat identification was not addressed.

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Conclusions (2)

- A simple ocean clutter model agrees well with measured data acquired under different environmental conditions
- Atmospheric refractive effects can cause significant variations in the infrared scene
- SIRST performance may be radically reduced under certain atmospheric conditions
  - Refractive shadow zones may exist under some conditions
  - Additional data on temperature lapse rate are needed to determine the frequency of occurrence of this phenomenon.